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US-PAT-NO: 6775295

DOCUMENT-IDENTIFIER: US 6775295 B1

TITLE: Scalable multidimensional ring network

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Application Filing Date - AD (1):

20000323

Drawing Description Text - DRTX (8):

FIG. 7 is a process flow diagram illustrating a process implemented on each node for determining whether to transmit locally generated packets downstream on the network and whether to transmit downstream available bandwidth information upstream.

Detailed Description Text - DETX (23):

The ring networks 52, 54, 56, etc. in one embodiment of the invention are bi-directional rings that transfer packets in both an upstream direction and a downstream direction. The ring networks connecting nodes 42 together can be implemented over Wide Area Network (WAN) links and/or Local Area Network (LAN) links and/or any other bus or backplane interconnection.

Detailed Description Text - DETX (27):

Two types of information are sent on the rings, data and control information. Preferably, as data is sent downstream in a clockwise direction by the outer ring, control information for managing the data traffic on the outer ring is sent upstream or counterclockwise on the inner ring. Likewise, as data packets are sent downstream in a counter clockwise direction on the inner ring, control information for management traffic on the inner ring are sent upstream or clockwise on the outer ring. Thus, each ring uses the other to send control information in a direction that is opposite to the direction that data packets are traveling.

Detailed Description Text - DETX (28):

In one embodiment, separate control packets are not generated for the control information. Instead, control information for the other ring is piggybacked in each data packet as part of a packet header. If no data packets are being sent on one ring, then a special empty packet is generated so that control information is sent upstream for the other ring. Separate control packets may also be generated. For purposes of this discussion, whenever a control packet is referred to, it should be understood that a special control packet or part of a data packet, such as a space reserved in a data packet header, could also be used. Control information is carried upstream to nodes about the bandwidth that is available to other nodes downstream. As is

described below, this information is used by each node to allocate to itself a fair amount of bandwidth for transmitting locally generated messages. In this context, a fair amount of bandwidth does not necessarily mean an exactly equal amount of bandwidth to other nodes, although it will be close to equal. The bandwidth is fairly determined by each node.

Detailed Description Text - DETX (29):

Each node implements the spatial reuse protocol by determining a fair amount of allocated bandwidth based on the bandwidth available to downstream nodes. Also, each node determines when control information should be sent upstream indicating that the node or nodes downstream are not receiving enough bandwidth. This is done by keeping track of four quantities: local transmit usage, downstream usage, allocated usage, and forward rate.

Detailed Description Text - DETX (39):

The description above shows how each node determines a fair amount of allocated usage for the node. When downstream nodes have limited bandwidth available for transmitting data, a message is sent upstream indicating the amount of bandwidth available to the downstream nodes. Each node evaluates control information received from downstream nodes and decreases its allocated usage if it has allocated more bandwidth to itself than downstream nodes are currently receiving. Before describing how each node uses the allocated bandwidth to determine whether or not to send data, it will be useful to consider an example of how network bandwidth is shared in a fair and efficient manner with spatial and local reuse when the nodes implement the spatial reuse protocol described above.

Detailed Description Text - DETX (40):

Returning to FIG. 5, consider a case where node 202 is transmitting to node 204 using links 212 and 213 on the outer ring. If no information is received by node 202 indicating downstream available bandwidth, the allocated usage for node 202 increases until it reaches the maximum allowed allocated usage. Thus, links 212 and 213 become completely devoted to carrying data transmitted by node 202. If node 203 needs to transmit to node 204, it immediately notices that it is forwarding data at a rate that prevents it from transmitting any of its own data onto the network. It has a very low local transmit usage and since its local transmit usage is less than its forward rate, it sends information upstream to node 202 indicating the available bandwidth for node 203. When node 202 receives indication of a low downstream available bandwidth, it decreases its allocated usage and reduces amount of its own data that it is transmitting on the network. Then, node 203 is able to transmit some of its own data onto the network.

Detailed Description Text - DETX (42):

The forward rate is used by each node to determine whether or not downstream available bandwidth information should be forwarded upstream. Since, as described above, downstream allocated bandwidth is used by nodes to reduce the amount of bandwidth that is allocated for transmitting locally generated data, it is desirable that downstream allocated bandwidth not be forwarded to nodes that are not contributing to congestion. This is accomplished by having nodes

only forward information indicating downstream available bandwidth if the local transmit usage of the node is less than the forward rate for the node. Thus, when a node receives information indicating downstream allocated bandwidth, the node determines whether or not its local transmit usage exceeds its forward rate. If its local transmit usage exceeds the forward rate, then the traffic congestion experienced downstream is caused primarily by that node and not by upstream nodes. Therefore, the node does not forward the downstream allocated bandwidth upstream. This enables the network to efficiently achieve local reuse.

Detailed Description Text - DETX (46):

It should be noted that decisions whether or not to send information upstream indicating downstream available bandwidth are made by each node when the node has locally generated data that it needs to transmit on the network. The following description will show how each individual node determines whether it can send data on the network based on the state of its transit buffer and its allocated usage.

Detailed Description Text - DETX (48):

Actually, the node checks whether the amount of data stored in the transit buffer is less than a certain threshold. The threshold is usually some amount below the full capacity of the transit buffer to allow for a safety factor to prevent packets from being dropped that are supposed to be forwarded. Additionally, in one embodiment, the threshold is further reduced to allow for priority data. When the node wants to transmit its own packets onto the network from the packet transmission buffer and it determines that its ability to do so is limited by packets being forwarded from upstream nodes through the transit buffer, then that node piggybacks information indicating the amount of bandwidth that is available to the node on a packet that is sent upstream. In one embodiment, space is reserved in packet headers for downstream available bandwidth information. By indicating its local transmit usage to upstream nodes that implement the spatial reuse protocol, the downstream node insures that it will eventually have available to it a fair amount of network bandwidth. The process by which a node determines whether or not to send downstream available bandwidth information upstream and whether or not to transmit its own packets when the transit buffer is below the threshold is further described below.

Detailed Description Text - DETX (49):

FIG. 7 is a process flow diagram illustrating a process implemented on each node for determining whether to transmit locally generated packets downstream on the network and whether to transmit downstream available bandwidth information upstream. The process starts at 400. In a step 402 the node determines whether or not the transit buffer has a high priority packet in it. If it does, then control is transferred to a step 404 where the node determines whether or not its forward rate is greater than its allocated usage. If the forward rate is greater than its allocated usage, then control is transferred to a step 406 and a flag is set indicating that a notification of downstream available bandwidth should be forwarded upstream. As described above, when upstream packets are sent, downstream available bandwidth is then included with

the packets in the packet header. The time that the flag remains set may be adjusted to tune performance.

Detailed Description Text - DETX (57):

Thus, the node regulates the amount of its own traffic that it transmits on the network according to its allocated usage and the node sends information upstream indicating downstream available bandwidth when local transmit usage is less than allocated usage.

Claims Text - CLTX (1):

1. A multidimensional ring network, comprising: a plurality of nodes arranged into a plurality of node sets; multiple ring networks each coupling three or more of the nodes in one of the node sets together; the multiple ring networks connected together to form a logical 3 or more dimensional ring matrix network where each dimension of the 3 or more dimensional ring matrix network includes three or more of the ring networks and the nodes at each logical edge of the ring matrix network are coupled directly to the nodes at each opposite corresponding edge of the ring matrix network; network interfaces for each one of the nodes configured to send and receive packets in an upstream direction and a downstream direction on the ring networks; and packet controllers on each one of the nodes configured to allocate a bandwidth for locally generated network packets sent in the downstream direction wherein the packet controller determines a minimum downstream available network bandwidth available in the downstream direction from information received in the upstream direction and adjusts the local allocated bandwidth based on the minimum downstream available network bandwidth, periodically increasing the local allocated bandwidth toward a maximum local allocated bandwidth and wherein the packet controller uses the local allocated bandwidth to govern whether a class of locally generated network packets are sent in the downstream direction.

Claims Text - CLTX (2):

2. A ring architecture, comprising: multiple network processing nodes logically arranged along multiple axes; multiple ring networks each connecting together at least three of the network processing nodes that are logically arranged along a same axis, each one of the multiple ring networks connecting all of the nodes on the same axis together in sequence and connecting the nodes on opposite ends of the same axis directly together in a ring configuration, at least three of the ring networks logically coupling the network processing nodes together along at least three first parallel axes and at least three additional ring networks logically coupling the same network processing nodes together logically along at least three second axes perpendicular to the first axes to form a first at least 3.times.3 lattice interconnected ring network where each one of the network processing nodes on the ends of the lattice are directly coupled to the network processing nodes on corresponding opposite ends of the lattice; additional at least 3.times.3 lattice interconnected ring networks formed along each axis of the first lattice interconnected ring network; network interfaces for each one of the nodes configured to send and receive packets in an upstream direction and a downstream direction on the ring networks; and packet controllers on each one of the nodes configured to allocate a bandwidth for locally generated network packets sent in the downstream direction wherein the packet controller determines a minimum

downstream available network bandwidth available in the downstream direction from information received in the upstream direction and adjusts the local allocated bandwidth based on the minimum downstream available network bandwidth, periodically increasing the local allocated bandwidth toward a maximum local allocated bandwidth and wherein the packet controller uses the local allocated bandwidth to govern whether a class of locally generated network packets are sent in the downstream direction.

US-PAT-NO: 6125396

DOCUMENT-IDENTIFIER: US 6125396 A

TITLE: Method and apparatus for implementing bandwidth allocation with a reserve feature

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Application Filing Date - AD (1):

19970327

Detailed Description Text - DETX (25):

In step 330, an amount of usage is allowed based on the assigned usage rate and the reserve. If the excess of the desired usage rate over the assigned usage rate corresponds to a usage less than or equal to the reserve, then the amount of usage allowed is the amount equivalent to the desired usage rate. Otherwise, the amount of usage allowed is limited by the assigned usage rate and the reserve. Control then passes to step 340.

Detailed Description Text - DETX (26):

In step 340, the reserve is decremented. The reserve is decremented by the amount of the reserve used to supplement the allowed usage in step 330. Note that the reserve is never decremented below zero because the amount of the reserve used to supplement the amount of usage allowed never exceeds the amount of data in the reserve. Execution of the steps ends until the steps are invoked again.

Detailed Description Text - DETX (43):

Table 430 shows various states after each access by non-real-time client 400 of shared resource 428. The columns from left to right are the time interval, the desired usage rate, the assigned usage rate, the allowed usage, the increment or decrement of the reserve, and the reserve after execution of the steps in each time interval. The columns representing amounts of data contain numbers expressing a rate in blocks/sec. In the increment or decrement column, increments are represented by positive integers, and decrements are represented by negative integers.

Detailed Description Text - DETX (45):

In step 350, the usage rate allowed is the desired usage rate, which is 10 blocks/sec. Therefore, non-real-time client 400 accesses shared resource 428 at a rate of 10 blocks/sec. At step 360, a determination is made of whether the desired usage rate is less than the assigned usage rate. Because the desired usage rate is equal to the assigned usage rate of data, the reserve is not incremented and execution of the steps ceases.

Detailed Description Text - DETX (54):

In step 330, an amount of usage is **allowed based on the assigned usage** rate and the reserve. The difference between the desired usage rate and the assigned usage rate is 2 blocks/sec. The reserve contains 5 blocks of data. Based on the period of time between the time intervals, which is 1 second, the difference is the equivalent of 2 blocks. Because the difference of 2 blocks is less than the reserve of 5 blocks, the **allowed usage** rate is the desired rate of 12 blocks/sec. Control then passes to step 340.

Detailed Description Text - DETX (57):

In step 330, an amount of usage is **allowed based on the assigned usage** rate and the reserve. The difference between the desired usage rate and the assigned usage rate is 4 blocks/sec. Based on the period of time between the time intervals, which is 1 second, the difference is the equivalent of 4 blocks. The reserve contains 3 blocks of data. Because the difference of 4 blocks is greater than the reserve at 3 blocks, only the amount in the reserve is used to provide the amount of usage allowed. The usage allowed is 13 blocks, which is less than that which would be provided at the desired usage rate of 14 blocks/sec. Control then passes to step 340.

Current US Cross Reference Classification - CCXR (4):

709/232

Current US Cross Reference Classification - CCXR (5):

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